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Snakes and ladders: A review of ball python production in West Africa for the global pet market

Lauren A. Harrington[1], Jennah Green[2], Patrick Muinde[2], David W. Macdonald[1], Mark Auliya[3,4], Neil D'Cruze[1,2]

1 *Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Recanati-Kaplan Centre, Tubney House, Abingdon Road, Tubney, Abingdon OX13 5QL, UK* **2** *World Animal Protection, 222 Gray's Inn Rd., London WC1X 8HB, UK* **3** *Zoological Research Museum Alexander Koenig, Department Herpetology, Adenauerallee 160, 53113 Bonn, Germany* **4** *Department of Conservation Biology, Helmholtz Centre for Environmental Research GmbnaH–UFZ, 04318 Leipzig, Germany*

Corresponding author: Lauren A. Harrington (lauren.harrington@zoo.ox.ac.uk)

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Abstract

The ball python (*Python regius*) is the most traded, CITES listed, live animal exported from Africa. Recent studies have raised concerns as to whether production methods in Africa are sustainable, humane and compliant with legislation. To aid future management we explored export patterns, using the CITES and U.S. LEMIS database, for live ball pythons from across their range in West Africa to identify the main exporters and the main markets supplied, and to assess associated trends, and compliance with nationally-established export quotas. We found that export to supply the global pet trade remains almost exclusively carried out by three range countries – Benin, Ghana, and Togo. The USA was the largest importer from all three countries, although Ghana appeared to be less dependent on the USA market than either Togo or Benin, exporting to a more diverse range of countries, particularly in Asia. Between 2003 and 2017 there was a decline in annual importer-reported exports from Benin and from Ghana, but not from Togo. Ghana appears to operate as a regional trade hub, re-exporting ball pythons imported from Benin and Togo, and exports more ball pythons reported as captive-bred. Trade records from all three countries exhibited a switch from predominantly wild-sourced to predominantly ranched individuals. However, at a range-wide level, differences in the use of source codes among exporting range states, and inconsistencies in reporting of trade among range states, as well as inconsistencies in the use of source codes between exporting and importing countries, represent areas of potential concern. We recommend a regional-level policy approach for this highly sought-after species, to safeguard ball pythons and local livelihoods.

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Keywords
CITES, *Python regius*, ranching, reptile, wildlife trade, Benin, Ghana, Togo

Introduction

International wildlife trade can only be sustainable if harvest (or offtake) at the national level is sustainable (Leader-Williams 2002) and thus, for species that are distributed across multiple countries, sustainability must depend not only on the level of use within one range state but collective use within all range states across the species' natural distribution. Accordingly, for wide-ranging species subject to use and trade, effective conservation management requires an understanding of where (across the species' range) exploitation and fragmentation of populations is greatest. This information provides the basis for appropriate regulation, and the necessary adaptive management that underpins legal trade. Harvest quotas, for example, are set and implemented at a national level, but are complicated by the fact that (in the absence of physical barriers) both wildlife and people move across borders (e.g., Bräutigam et al. 1994; Eniang et al. 2008; Bassey et al. 2010; Ayilu et al. 2016). In particular, people hunt, sell and trade wild animals (legally and illegally) across borders in accordance with variation in local abundance (of the species), hunting and trade regulations, enforcement, and markets (e.g., Shepherd and Nijman 2007; Selier et al. 2014; Krishnasamy et al. 2018; Nowak 2019). At an international level, identification and understanding of trade chains is complicated by additional trade links among source countries, disparities in reporting among them, and differences in destination (market) countries (which might influence trends in demand) (cf. Carpenter et al. 2004; Blundell and Mascia 2005; Robinson et al. 2015).

In this study we explore export patterns for live ball pythons (*Python regius*) from across their West African range, focusing specifically on captive-production systems. Ball pythons are an internationally renowned and popular pet, particularly in the USA, where they are sourced from both domestic captive breeding and international export from range countries (cf. McCurley 2005; Prestridge et al. 2011; Herrel and van der Meijden 2014; D'Cruze et al. 2020a). Among all African species that are listed under CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and traded alive, ball pythons (listed on Appendix II of CITES, i.e. species for which trade is permitted, but regulated, to avoid utilization incompatible with their survival) represent the most common in terms of quantity (CITES Secretariat 2012). In an attempt to sustainably meet international consumer demand for this species, some range countries have adopted the use of ranching to produce ball pythons for export (e.g., Ineich 2006) where "ranching" is defined by CITES as "*rearing, in a controlled environment of animals taken as eggs or juveniles from the wild where they would otherwise have had a very low probability of surviving to adulthood*" (Lyons et al. 2017). Between 1996 and 2012 there was an almost 50-fold increase in global imports of ranched reptiles, dominated by ball pythons from Africa (Robinson et al. 2015), which were exported predominantly from Benin, Ghana and Togo (Toudonou 2015).

Native to western Africa and northern parts of central and eastern Africa, ball pythons occur in a wide range of savannah habitats, including open woodlands, rainforest margins, forest/plantation mosaics, and agricultural land, from Senegal to South Sudan and Uganda (Auliya and Schmitz 2010; see also Luiselli and Angelici 1998; Fig. 1). Ball pythons are predominantly nocturnal and are hunted during the day when they can be found resting in abandoned rodent burrows, termite mounds, or under dead oil palm trees and piles of grass and leaves (Harris 2002; D'Cruze et al. 2020b). To supply juvenile pythons for export, hunters collect neonates and gravid females (predominantly between January and March), the latter kept (by the hunters themselves or supplied to holding facilities) until the eggs are laid (D'Cruze et al. 2020b). According to hunters, females are typically later released back into their capture area (D'Cruze et al. 2020b), although it is not clear how long they are kept, when they are released, or what the specific release protocol is. Hunters also collect clutches of eggs (usually in February and March) that are sold directly to the farms (D'Cruze et al. 2020b) where they hatch approximately two months after laying (Aubret et al. 2003). The majority of juvenile snakes are exported post-hatching at 15–30 days of age (Sambo, pers. comm.; 15 April 2019) (under CITES Appendix II permit) and a proportion (in Togo approximately 20%) are released (Ineich 2006), although it is unclear on what basis the proportion to be released is determined.

Locally, in range countries, ball pythons are also taken from the wild for bushmeat, leather and use in traditional medicine (Auliya and Schmitz 2010; Segniagbeto et al. 2013; D'Cruze et al. in 2020c). Here we are concerned only with live exports for the international pet trade, which is considered the biggest threat to the species' conservation status (Auliya and Schmitz 2010). Our aim was to gain an objective understanding of the relative role played by each of the three main range states – Benin, Ghana and Togo – in the export of ball pythons. Specifically, we used CITES trade data, with additional data from the U.S. Fish and Wildlife Service Law Enforcement Management Information System (LEMIS), to assess trade trends (in numbers of animals involved, animal source, and compliance with export quotas reported to CITES), identify the markets (importing countries) supplied (and apparent trends in those markets), and the number of source-country exporters involved. A key aspect of the analysis was to quantify (as far as possible) formal and informal trade links between the three main source countries. Our trade analysis provides general lessons for many regionally-occurring species traded by multiple countries, particularly those for which there are clear links between in-situ (wild) and ex-situ (captive) sources that may cross national borders.

Ghana, Togo and Benin

The centre of the ball pythons' distributional range is Ghana (238,535 km^2) and Benin (112,622 km^2) that frame Togo (56,790 km^2) to the west and east, and in the south all three countries have a coastline to the Gulf of Guinea (Fig. 1). These three countries are recognised as the main reptile exporters of sub-Saharan western Africa with several species being harvested at significant levels for the international "exotic" pet trade (Affre et al. 2005), and Lomé, the capital of Togo, is a major hub for international live reptile export,

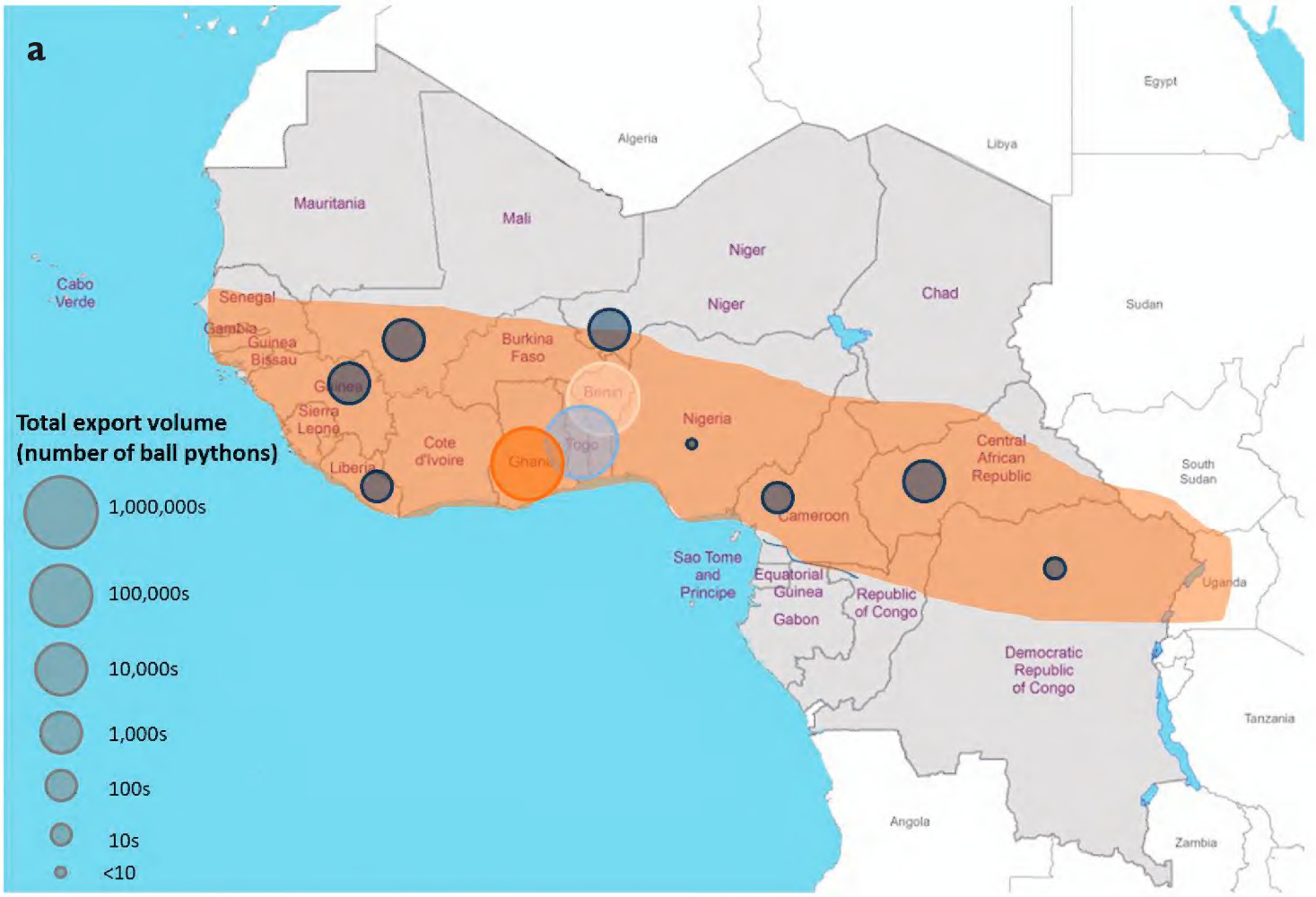

Figure 1. a Approximate distributional range of ball pythons in west and central Africa (shaded orange), showing relative export volume (number of individuals) of ball pythons exported from range states (depicted as proportionally-sized circles), 1978–2017. **b** Trends in annual exports for the three main exporting countries and all others combined. Species range from Auliya and Schmitz (2010) and Barker and Barker (2006). Trade data based on importer-reported quantities from the CITES Trade Database (http://trade.cites.org/).

particularly snakes (Jensen et al. 2019). International trade of ball pythons is regulated through CITES, an international agreement, that opened for signing in 1973 and entered into force in 1975. Ghana joined CITES in November 1975 (entering into force in February 1976), followed by Togo in October 1978 (entering into force in January 1979)

while Benin did not join CITES until February 1984, almost 10 years later (entering into force in May of 1984). According to CITES records, export quotas [see CITES Res. Conf. 14.7 (Rev. CoP15)] for ranched ball pythons from Benin, Ghana and Togo, and wild-caught ball pythons from Ghana and Togo, were all established by 1995 (CITES Notification No. 874). In Benin, the commercial export of wild-caught ball pythons was suspended in 1993 (CITES Notification No. 839), and quotas for the export of wild-caught individuals re-established in 1999 (CITES Notification No. 1999/21). Most recently, in 2008, Ghana also established quotas for captive-bred specimens (UNEP 2019).

Methods

All trade records pertaining to ball pythons exported alive from range states (as listed on the IUCN Red List) were downloaded from the CITES Trade Database (https://trade.cites.org/) in September 2019. We included all importing countries and territories (as listed by CITES), and all source codes (as outlined in Lyons et al. 2017), and purposes of trade (as defined in UNEP-WCMC 2013) (note that source codes have only been recorded since 1990). Data were downloaded as a comparative tabulation. Export quotas for Benin, Ghana and Togo, communicated with CITES, for ranched, wild, and captive-bred specimens (available since 1997), were obtained from the Species+ website (UNEP 2019). First, we described total native range exports and quantified the relative role of Benin, Ghana, and Togo, alongside other range countries actively exporting ball pythons. Second, for each of Benin, Ghana and Togo, we quantified total ball python trade (number of individuals exported, purpose, and source) between 1978 and 2017 (2018 data were not available at the time of the study), used time series analysis to assess trends, identified those countries providing the largest share of the market, and compared numbers reported traded with annual country export quotas. For analysis, both exporter- and importer-reported annual quantities in trade records were used, and compared; where numbers from only one dataset are presented, the dataset was selected based on completeness, and the dataset used stated in the text. Each "live animal" reported was presumed to represent an individual animal. For an earlier analysis of a subset of these data on ball python trade from Togo see D'Cruze et al. (2020e).

Additional trade data, for the period 2000–2017, detailing individual export and import companies, were obtained from the U.S. Fish and Wildlife Service Law Enforcement Management Information System (LEMIS) via a Freedom of Information Act (FOIA) request submitted to the Fish and Wildlife Service, Office of Law Enforcement (received on 8 May 2018, control number FWS-2018-00788). This level of information was only available for ball python trade to the USA.

Finally, to provide further insight on global market trends, for those importing countries (or regions) identified as important for range country exports, we repeated the CITES data collation (in November 2019) using all live ball python trade records from all exporting countries. For all major importing countries (or regions) identified, we assessed overall import trends over time, and, for the USA, known to be a major

captive producer of ball pythons (McCurley 2005), we also assessed exports (trends over time, markets supplied, and animal source) (see Suppl. material 1).

Trade data were described using graphs and summary statistics. To test for trends over time in CITES trade records, we summarised the records by year and used the tslm function in the "forecast" package (Hyndman 2017) in R to fit linear models to the resulting annual time series data, and to quantify and test the significance of trends. The entire time series was plotted for visualisation, but trends were assessed quantitatively over the most recent 15 years (2003–2017) rather than the entire time series available, because this represents the time during which ranching has been used extensively to produce animals for export. Importing country trends were assessed graphically only. Analysis of variance (ANOVA) and post-hoc Tukey's tests were used to test for absolute differences in trade parameters among countries (including year as a factor in the model where appropriate). Chi-squared tests were applied to test for country-level differences in summary statistics (with post-hoc pairwise comparisons carried out using the pairwiseNominalIndependence function in the "rcompanion" package, Mangiafico 2019). For all tests, statistical significance was accepted at $p < 0.05$. All statistical analyses were carried out in R (version 3.5.1, R Core Team 2018).

Results

Range state exports, 1975–2017

The CITES Trade Database holds a total of 2,129 trade records of ball pythons exported from range states, documenting total exports of between three and four million individual ball pythons (exporter-reported exports: 3,121,022; importer-reported exports: 3,979,680) since the first recorded export of the species in 1975. Since that time, 11 of 18 range states exported ball pythons but only six reached total exports over the period of 5,000 or more: Benin, Ghana, Guinea, Mali, Niger and Togo. The following numbers are based on importer-reported data but the relative ranking of range states as ball python exporters is the same regardless of the specific dataset used. Exports from Mali peaked in 1995 at 5,750, and comprised 14.2% of annual ball python exports that year, but <3% the following year, and <1% in all other years. Exports from Guinea and Niger comprised a small proportion of annual exports in all years, peaking at 3.6 and 2.1% (in 1997 and 2005, respectively). In total, through the 1980s, 1990s and 2000s, exports from Benin, Ghana and Togo collectively comprised 98.8% of all ball python exports from range states (28.6%, 44.0% and 26.2%, respectively; Fig. 1). Exports of ball pythons from Guinea, Mali and Niger were last recorded in 2008, 2010 and 2009 (respectively), and, since 2011, Benin, Ghana and Togo were the only range states to have reported ball python exports. Guinea and Liberia have been under a CITES trade suspension for all commercial trade since 2013 (CITES Notification No. 2019/075), and 2016 (CITES Notification No. 2018/012), respectively, as was Guinea-Bissau between 2016 and 2018 (CITES Notification No. 2018/011).

Benin, Ghana and Togo exports and production, 1978–2017

Export volume and trends

In total, CITES trade records document the export of approximately one million live ball pythons from each of Benin, Ghana and Togo, up to 2017, over 99% of which were intended for commercial use. Annual country-level exports varied between 100 and over 100,000 individuals with similar patterns among the three countries: peaking in the mid-1990s (but not in Ghana) and in the early- to mid-2000s (Fig. 1b, Fig. 2). However, over the most recent 15 years (2003 - 2017), there was a statistically significant decline in annual importer-reported exports in Benin (from 82,303 to 19,577 per year; trend=-3246, $F_{1, 13} = 16.54$, $p = 0.001$; Fig. 2a) and in Ghana (from 77,510 to 13,887 per year; trend=-6625, $F_{1, 14} = 38.75$, $p < 0.001$; Fig. 2b), but not in Togo (trend=-1,021; $F_{1, 13} = 1.48$, $p = 0.246$) where annual exports averaged 54,800 per year but showed considerable fluctuation (SD = 14,296; Fig. 2c) (exporter-reported data were not used to assess recent trends due to missing data). Considering only exports in the most recent five years in which there were no missing data (2011–2015), and taking account of year effects, exports from Togo were statistically significantly higher (annual mean between 2011 and 2015 = 54,163) than from Benin (annual mean = 21,876; Tukey post-hoc test, $p = 0.001$) (but not Ghana: annual mean = 38,415; $p = 0.078$).

Countries differed in their tendency to under- or over-report exports (exporter-reported quantities < importer-reported quantities and vice versa, respectively; $\chi^2 = 9.22$, df = 2, $p = 0.010$, based on the frequency of cases) and in the absolute value of discrepancies between exporter- and importer-reported quantities (ANOVA: $F_{2, 83} = 7.46$, $p = 0.001$). Exports from Togo were statistically significantly more likely to be under-reported (exports under-reported in 75% of 32 years) than from Ghana (where exports were over-reported in 62% of 34 years; post-hoc pairwise comparison $p = 0.006$; Fig. 2a–c) and discrepancies in reported quantities from Togo were statistically significantly greater than from either Ghana (Tukey's post-hoc test, $p = 0.002$) or Benin ($p = 0.012$). Exports from Benin showed no particular tendency to be under- or over-reported (50% of 20 years reported in both cases), and did not differ from Ghana in terms of the absolute value of reporting discrepancies ($p = 0.989$).

Source

Trade records from all three countries exhibited a switch from predominantly wild-sourced to predominantly ranched individuals (albeit in the absence of extensive wild-sourced exports from Ghana prior to the uptake of ranching; Fig. 3). In all three countries, since approximately 2003 (up to 2017), an average of >90% of annual country-level importer-reported exports (excluding seizures) were documented "ranched" (source code R, or "born in captivity" [source code F]) and an average of

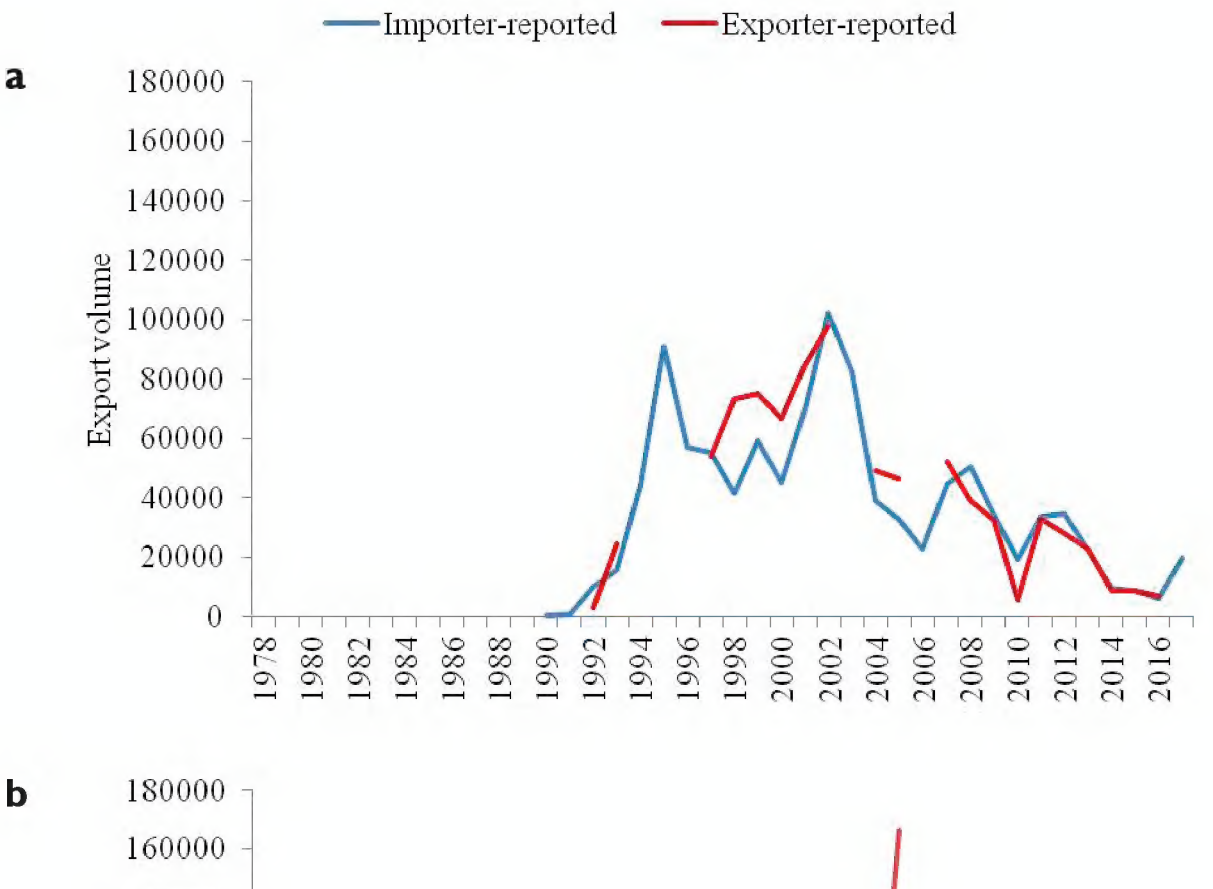

Figure 2. Annual export volume (number of individuals) of live ball pythons from Benin (**a**), Ghana (**b**) and Togo (**c**), as reported by both importing and exporting countries. Note: missing exporter-reported data in some years in all three countries. Source: CITES Trade Database (http://trade.cites.org/).

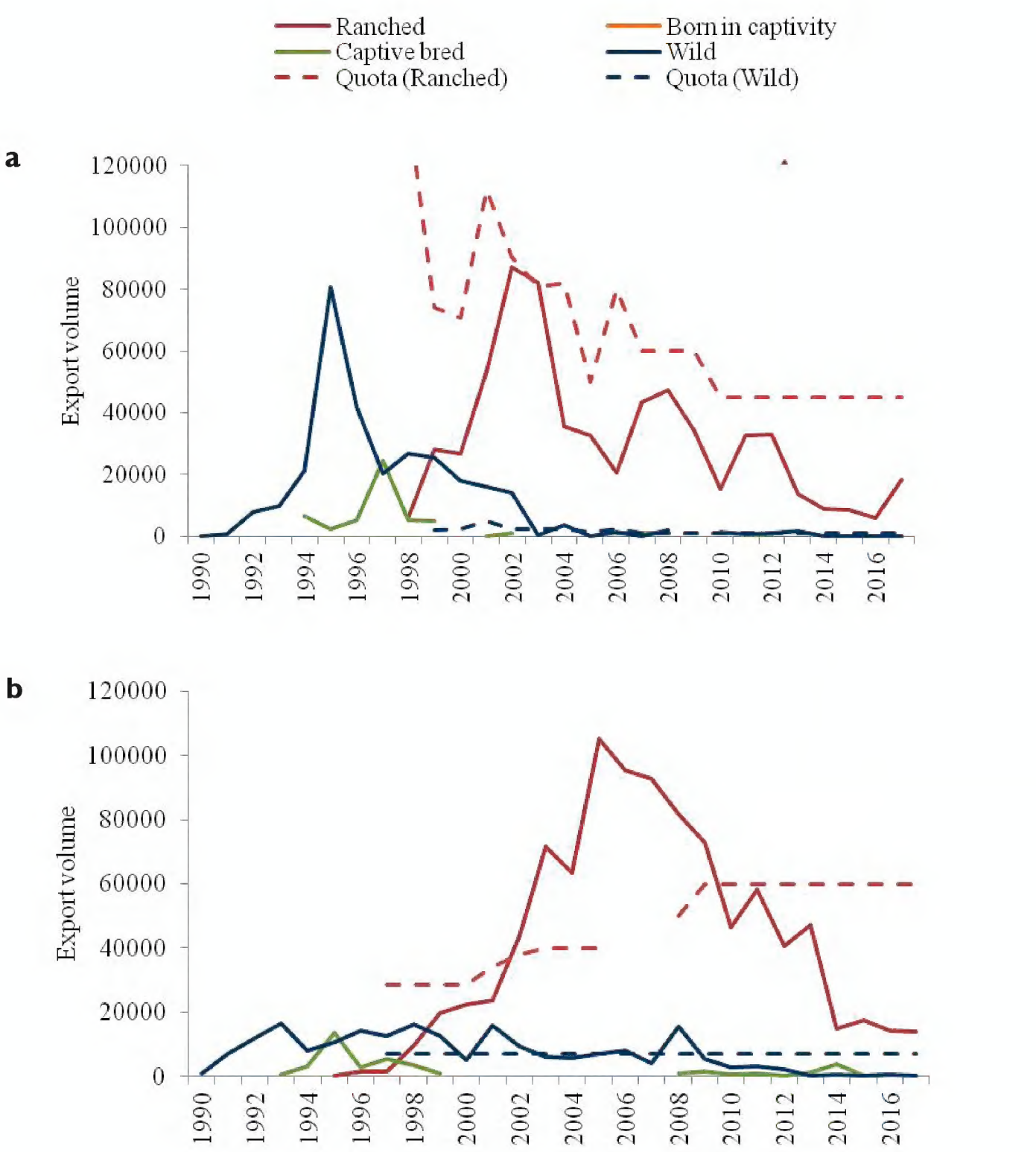

Figure 3. Source of annual exports (export volume, number of individuals) documented by Benin (**a**), Ghana (**b**) and Togo (**c**), based on importer-reported quantities in the period 1990–2017 (source codes were not recorded prior to 1990), together with export quotas (dashed lines) for ranched and wild specimens as communicated to CITES. Source codes defined as follows (Lyons et al. 2017): "Ranched" (R) = Specimens of animals reared in a controlled environment, taken as eggs or juveniles from the wild, where they would otherwise have had a very low probability of surviving to adulthood; "Bred in captivity" (C) = Animals bred in captivity in accordance with Resolution Conf. 10.16 (Rev.) (i.e. where parents mated in a controlled environment and where the breeding stock was established in a manner not detrimental to the survival of the species in the wild, and maintained [under normal circumstances] without the introduction of specimens from the wild); "Born in captivity" (F) = Animals born in captivity (F1 or subsequent generations) that do not fulfil the definition of "Bred in captivity" in Resolution Conf. 10.16 (Rev.) (e.g., parents did not mate in captivity, or the breeding stock/operations did not meet CITES requirements); Wild (W) = Specimens taken from the wild. Further detailed graphs in Suppl. material 1. Source: CITES Trade Database (http://trade.cites.org/) and UNEP (2019).

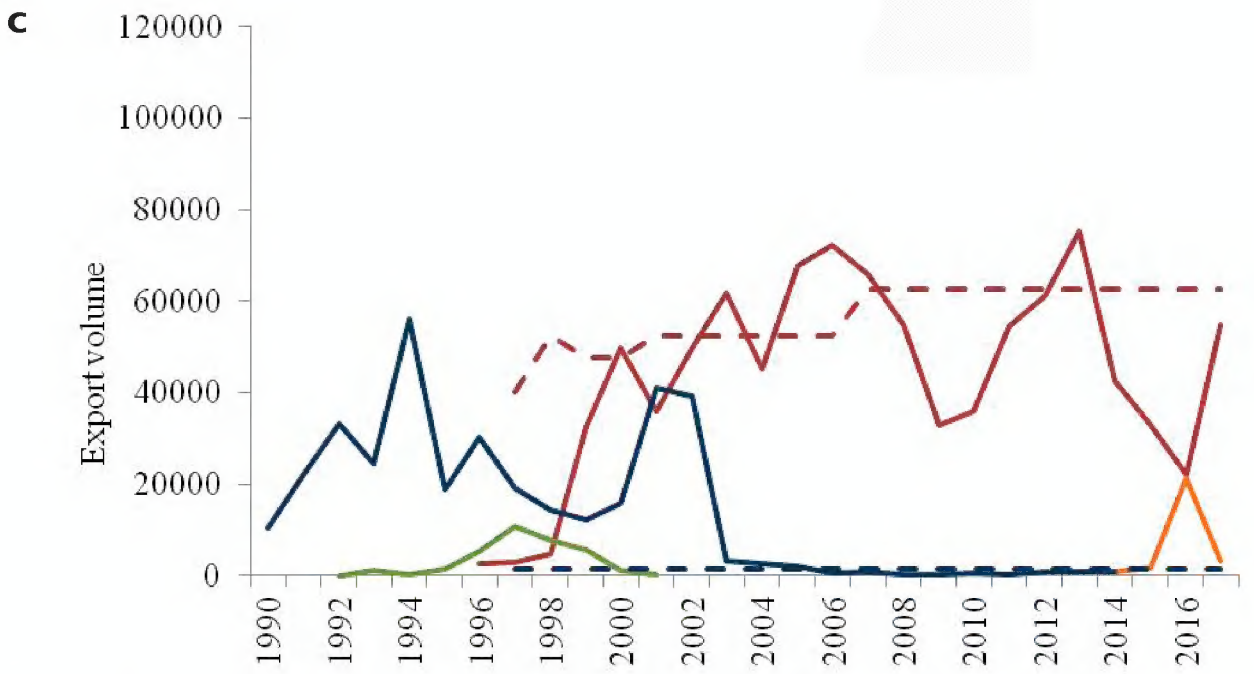

Figure 3. Continued.

< 6% were documented "wild-caught" (source code W; Fig. 3). However, the proportion of wild-caught individuals exported (post-2003) varied annually (ANOVA: $F_{1, 41} = 6.59$, $p = 0.014$) and among countries ($F_{2, 41} = 4.51$, $p = 0.017$), with Ghana, specifically, exporting a greater proportion of wild-caught individuals (maximum 15.9%, equating to 15,592 individuals, according to importer-reported quantities) as compared to Togo (annual maximum 5.2%, equating to 3,165 individuals; Tukey's post-hoc test, $p = 0.012$).

All three countries (post-2003) used additional alternative source codes representing different captive production systems; however, only Togo used the source code F, reporting a total of 26,782 individual ball pythons born in captivity exported between 2014 and 2017. All three countries used the source code C ("captive-bred") in the mid-1990s prior to the establishment of ranching (see Fig. 3); post-2003, use of this source code was limited (Fig. 3) but nevertheless accounted for up to 6% of Benin's exports (captive-bred individuals from Benin cannot be seen in the graph due to the low numbers and missing data in intermittent years but amounted to 1,000 individuals in each of 2006, 2007 and 2008, 600 in 2011 and 2012, and 1,200 in 2017) and up to 20% of Ghana's exports (in 2014, equating to 3,770 individuals).

U.S. Fish and Wildlife Service LEMIS import data listed a total of 51 unique export company names (inferred on the basis of similar spelling; n = 18, 22 and 11, respectively, in Benin, Ghana and Togo) that exported ball pythons to the USA between 2000 and 2017. Of the 51 export companies listed, only two to three (per country) operated in all years, and these were responsible for 64.8%, 71.8% and 88.3% (respectively, for Benin, Ghana and Togo) of total country exports to the USA. In Benin and Ghana, the number of export companies shipping ball pythons to the USA declined from eight and 11 in 2004 and 2005, respectively, to four and two in 2017. The number of export companies in Togo exporting to the USA in a single year was between two and six over the entire period (2000–2017; four in 2017).

Markets

CITES trade records document exports of ball pythons from Benin to 34 different countries/territories, and from both Ghana and Togo to each 57 different countries/territories (Suppl. material 2). The following is based on exporter-reported quantities. The USA was the largest importer from all three countries (Fig. 4). Over the most recent five years (2012–2016), the most significant importing countries/territories after the USA were: Hong Kong, the UK, France, Spain, and Ghana (albeit with each importing country/territory being the main importer for different exporting countries, Fig. 4). At a regional level, over the most recent five years, there was a statistically significant association between exporting country and importing regions ($\chi^2 = 65643$, df = 8, $p<0.001$) such that Ghana appeared to be less dependent on the USA market than either Togo or Benin, exporting to a more diverse range of countries and, specifically, exporting significantly more snakes to Asian countries (36.6% exports compared with 6.8% and 10.4% for Benin and Togo, predominantly Hong Kong, but also Japan and Taiwan). Western European countries were prominent as importers from all three countries, comprising 9.1%, 18.3% and 15.1% of exports from Benin, Ghana and Togo, respectively (Fig. 4). There was little intra-continental trade within Africa originating from range states (except between Togo, Benin and Ghana, Fig. 4; see *Trade links* below). The only African non-range states to play a role as importers were Egypt (another major hub for the export of snakes from the African continent; see Jensen et al. 2019) and South Africa. Collectively, African countries were responsible for receiving only 6.4%, 1.5% and 3.7% of exports from Benin, Ghana and Togo.

For three of the main importers (the USA, the EU combined as a region, representing mainly Spain, UK, France and Italy, and Hong Kong), broad trends in the number of ball pythons imported over time suggest that whilst the role of the USA and the EU as importers declined over recent years, the role of Hong Kong as a major importer (supplied by Ghana, Togo and the USA) increased (Suppl. material 3). In parallel, the role of the USA as an exporter increased, and the USA is now the fourth largest global exporter of ball pythons responsible for the supply of ball pythons to a range of countries on all continents, including the UK, Germany, Japan, Hong Kong, Canada and Mexico (Suppl. material 3). The source of ball pythons exported from the USA shows a switch first from wild-sourced to ranched (as indicated by export source above), and then from ranched to captive-bred individuals, thus demonstrating a shift from the USA operating as a re-exporter of ball pythons documented as ranched in range states to an exporter of their own in-country production (in addition to the supply of their own [unquantified] domestic market, Suppl. material 3). Germany now also exports up to 1,600 captive-bred ball pythons each year, and is the largest exporter after range states, the USA and Canada.

Quotas and CITES Compliance

There was no statistically significant difference among the three countries in their tendency to exceed export quotas (the number of years in which quotas were exceeded)

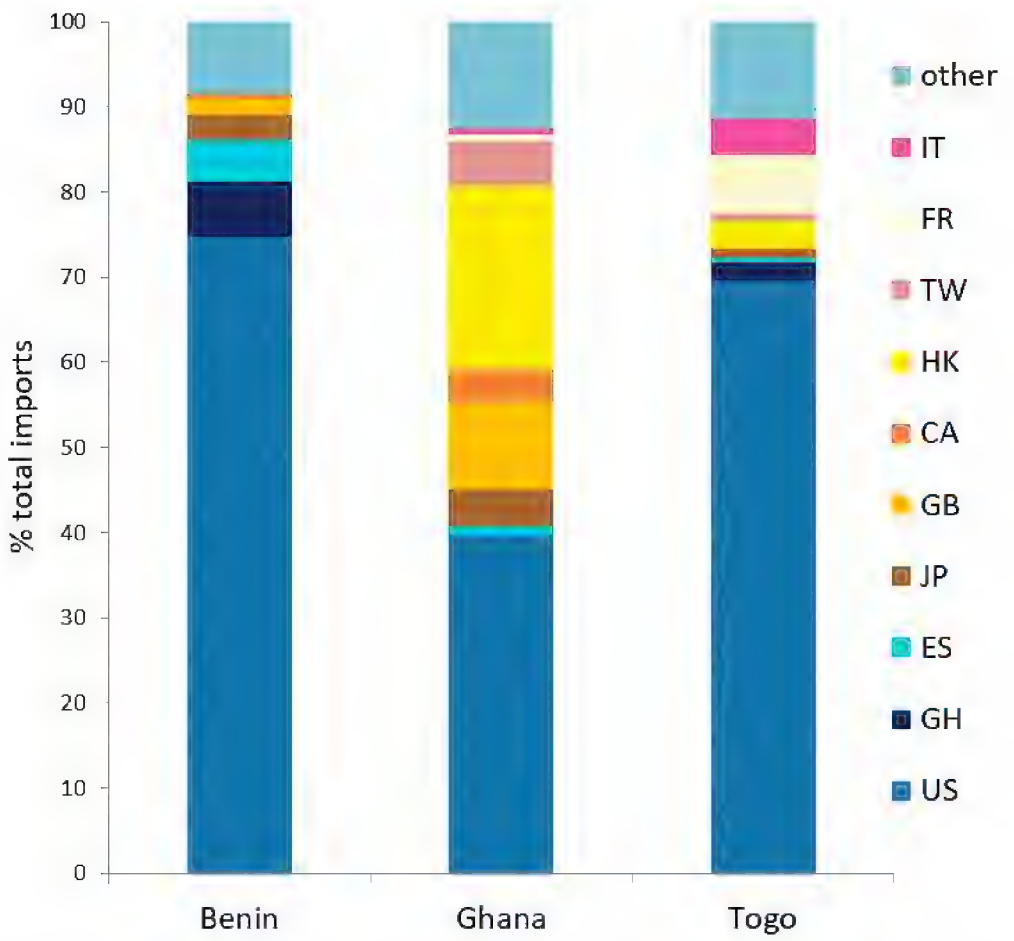

Figure 4. Countries importing live ball pythons exported from Benin, Ghana, and Togo, 2012–2016, shown as a proportion of total reported exports (based on exporter-reported quantities) from each country, including all countries responsible for importing 3% or more of total exports from at least one exporting country. US = USA, GH = Ghana, ES = Spain, JP = Japan, GB = UK, CA = Canada, HK = Hong Kong, TW = Taiwan, FR = France, IT = Italy. Note that for Ghana data are missing for 2016. Source: CITES trade database (http://trade.cites.org/).

over the 21 years included in the study for either ranched (number of years quotas exceeded = 1–8; $\chi^2 = 4.05$, df = 2, p = 0.132) or wild ball pythons (number of years quotas exceeded = 8–10; $\chi^2 = 0.96$, df = 2, p = 618; based on importer-reported quantities; Fig. 3). But the extent to which they exceeded quotas (the number of individuals in excess of specified quotas) was statistically significantly higher for Ghana, for ranched ball pythons, than Benin (ANOVA: $F_{2, 59} = 7.33$, p = 0.001, post-hoc pairwise test p < 0.001), and was statistically significantly higher for Togo, for wild-sourced pythons, than Ghana (although, for the latter, the country-wide comparison was not statistically significant [ANOVA: $F_{2, 57} = 2.98$, p = 0.059, post hoc pairwise test p = 0.047; based on importer-reported quantities; Fig. 3]). However, national export quotas communicated to CITES, and the rate and direction of quota adjustment over time, differed among countries. For example, the annual export quota in Ghana for ranched ball pythons was initially very low (28,500) and exports that were substantially higher than agreed quotas tended to occur during the period when the quota was low (Fig. 3b). During this period (in the early 2000s), the absolute volumes of live ball python exports from Benin and Ghana were not substantially different but the export quota in

Benin for ranched ball pythons was considerably higher (139,000, Fig. 3a). Ghana has since steadily increased its quota to 60,000 (Fig. 3b) whilst Benin has reduced its quota (Fig. 3a). Similarly, annual export quotas for wild specimens in Togo were exceeded on ten different occasions by up to 39,644 individuals (average 13,730) but Togo's quotas for wild-sourced pythons were the lowest of all three countries (1,500; Fig. 3c). Post-2003, wild caught quotas were exceeded rarely in any of the three countries, and by relatively small amounts (Suppl. material 1). In Ghana, animals declared to be captive-bred were exported in excess of quotas (200 individuals, established in 2009) in three of the last five years (2012–2016; Suppl. material 1). There is no quota in Togo for ball pythons born in captivity (source code F).

Trade links

Figure 5 summarises recent (2012–2016) ball python trade links among the three main range states of Benin, Ghana, and Togo. Most notable is the role of Ghana, that appears to operate as a trade hub, re-exporting ball pythons imported from Benin and Togo. Between 2012 and 2016, 6.4% of Benin's and 2.1% of Togo's exports were shipped to Ghana, most (>98%) were reported as ranched (although Ghana reported a proportion exported from Togo under source code F [born in captivity]), and most (c.90%) were then re-exported by Ghana to destinations outside Africa (Fig. 5). Since 2002 (and the broad-scale introduction of the ranching source code for ball pythons), 17% of ball pythons (n = 169,610, or 210–33,873 per year) exported from Ghana were reported to have originated from Benin, and 1.9% (n = 18,790, or 220–7,340 per year) from Togo. Reciprocal ball python trade from Ghana to Benin or Togo, and trade between Togo and Benin, was reported less frequently, inconsistently, and tended to involve smaller volumes. For example, Ghana reported the export of <1,000 (predominantly ranched) ball pythons to Benin since 2002 (800 between 2012 and 2016) but these were not reported as imports by Benin. In the year 2002, 2,000 ranched ball pythons exported by Benin were reported to have originated from Togo, but there were no recorded ball python exports from Togo to Benin. Similarly, 148 ranched ball pythons exported by Togo in 1981 (n = 70) and 2004 (n = 78) were reported to have originated from Ghana but there were no matching export/import records.

Other range states were represented (as animal origin or importers) in CITES trade records to a lesser extent, and the countries involved changed over time. In the 1990s, a proportion of ball pythons exported from Benin were reported to have originated from Burkina Faso (n = 2,987), Guinea (n = 2,200) and Mali (n = 2,850), c. 3,000 wild ball pythons exported by Togo were also reported to have originated from Mali, as did 440 exported by Ghana. More recently, in 2017, 75 ranched ball pythons exported by Togo reportedly originated from Senegal, and, in 2013, 4,000 ball pythons (also ranched) originated from Chad (although the latter is a regional country and not listed on the IUCN Red List as a range state per se). There were no export records for ball pythons from either Senegal or Chad to Togo. Togo also reportedly exported c. 800 ball pythons to Niger.

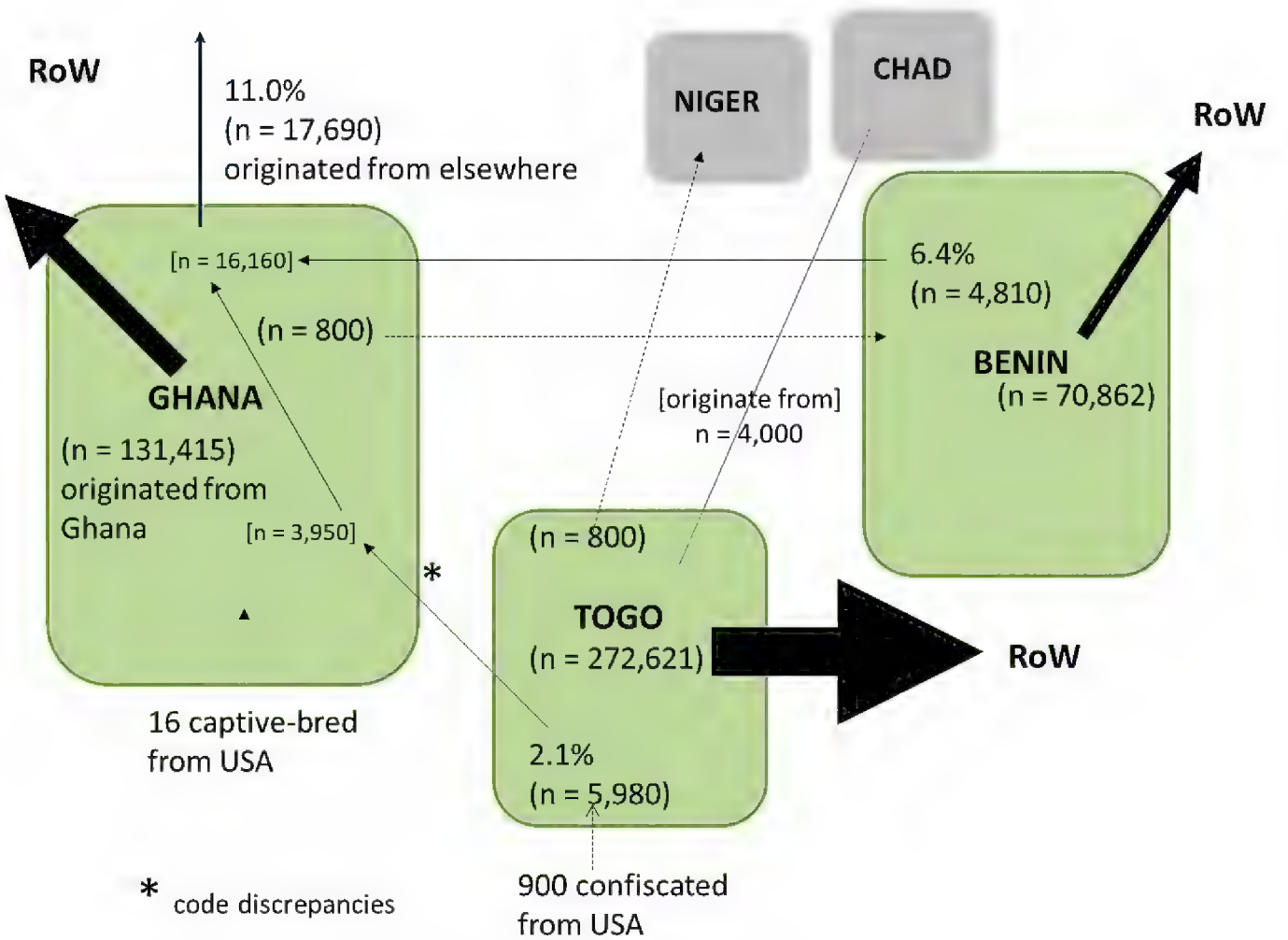

Figure 5. Exports to and from range states, 2012–2016 (including Chad which is a regional country but not listed on the IUCN Red List as a range state for ball pythons). Arrows show direction of export/import and are proportional to numbers exported. Note that 2016 figures were not available for Ghana. RoW = 'Rest of World'. Data source: CITES Trade Database (http://trade.cites.org), based on all live ball python trade records involving range states.

Discussion

Overview

Despite the relatively extensive geographical range of ball pythons, CITES trade data show that ball python production to supply the global pet trade, from within range states, remains almost exclusively sourced from three countries in the centre of their range–Benin, Ghana, and Togo (see also Toudonou 2015). Predominantly taken directly from the wild in the 1980s and 1990s, all three countries switched to ranching as the dominant reported production method in the early 2000s (see Gorzula et al. 1997). Togo has maintained relatively high levels of ranch production in recent years, but CITES trade records suggest that Benin and Ghana have not. It is not clear whether this decline in exports, from Benin, and to a lesser extent Ghana, was a conservation strategy designed to maintain exports within agreed quotas or a consequence of declining wild ball python populations required to supply production.

A significant proportion of exports from Ghana originate from Benin and Togo, implying that Ghana operates as a re-exporter (see also Pernetta 2009) in addition to a

harvester of its own resources. Ghana also supplies a slightly different and more diverse market than Togo and Benin (Fig. 4), relying more on the Asian than the USA market, and exports more reportedly captive-bred specimens (Suppl. material 1). Africa exports over 100 live reptile species to Asia (notably, in addition to ball pythons, leopard tortoises *Stigmochelys pardalis*), and whilst exports along this trade route have increased in recent years, there has also been an increase in reports of captive-bred specimens of a number of species (Outhwaite and Brown 2018). In Benin, production in recent years has been half to a third that of Ghana and Togo (Fig. 5) and management authorities of Benin have further reduced quotas of ranched specimens to 22,000 in 2018 (UNEP 2019), perhaps in response to reports from hunters and farmers that ball pythons in Benin have declined in number and may be extirpated in some areas (see Toudonou 2015). Export quotas for ranched individuals in Togo and Ghana (as of 2019) remain at 62,500 and 60,000 (UNEP 2019), respectively. However, in recent years Ghana has exported far fewer snakes than its quota allowed (Fig. 3), whilst Togo, despite being the smallest of the three countries, largely fulfils its quota (which may, in part, be supported by informal cross border trade at the local level, D'Cruze et al. 2020b, below).

At a range-wide level, differences in the use of source codes among exporting range states, and inconsistencies in reporting of trade among range states, as well as inconsistencies in the use of source codes between exporting and importing countries, may suggest irregular trading and/or improper ranching procedures, creates confusion in monitoring ball python trade, and represents an area of potential concern (CITES AC28 Com. 5). Since 2014, a proportion of ball python exports from Togo have been declared (by Togo, and by importing countries) as source code F (born in captivity, Fig. 3) rather than R (ranched). The CITES definition for animals "born in captivity" (see Lyons et al. 2017) may be a more appropriate descriptor of individual pythons from eggs of gravid females brought in to farms during what is otherwise described as "ranching" (see D'Cruze et al. 2020b); however, hunters in Togo sell eggs and snakes to farms in Benin and Ghana (D'Cruze et al. 2020b) but neither of these countries uses the source code F in their export reports to CITES (nor do countries importing from Benin or Ghana). Whilst it is possible that the source code F is being used in Togo, for example, by new staff, or under new guidance, that has not yet been adopted elsewhere, it is also possible that since there is no quota for ball pythons born in captivity it provides a useful loophole (i.e. classifying a proportion of exports as "F" may be a mechanism to maintain export volumes of ranched specimens within agreed quotas, see Fig. 3).

Domestic legislation

A brief review of the legislation in each of Benin, Ghana and Togo highlights some contradictory text regarding the legality of the practice of ranching in these countries. In Benin, for example, a license is required by Law No. 2002–16 (2004) for the harvest, market or export of "partially protected species" (which includes ball pythons), whether for personal or commercial purposes. Collection of the eggs of partially protected species

is also permitted on a limited basis but, under Article 154, it is an offence to hunt gravid females or juveniles. Since females and their juveniles of partially protected species are stated to be treated as fully protected species (Article 33), Article 36 also suggests that these animals should not be kept (except under exceptional cases for scientific purposes).

In Ghana, ball pythons are partially protected under Schedule II of the Wildlife Conservation Regulations of 1971 that prohibit hunting, capturing or destroying any species listed in Schedule II between August 1 and December 1 of each year, and hunting, capturing or destroying juveniles, or adults accompanied by juveniles, at all times. Outside of these restrictions ball pythons may be captured with possession of a valid licence according to Article 6 of the 1971 Regulations.

In Togo hunting permits are required by Articles 78, 79, 80 and 81 of Law No. 2008–09 of the Carrying Forest Code (2008) but discussions with hunters (D'Cruze et al. 2020b) suggest that not all hunters have them. Furthermore, as in Benin, it is unclear whether (even in the possession of a permit) the hunting of gravid females, juveniles, eggs and the associated destruction of ball pythons burrows (as described in D'Cruze et al. 2020b) can be carried out legally given that this activity is strictly forbidden under Article 78 of the Carrying Forest Code (2008). In Togo, sustainable management (see below) is required under Article 61 of the 005 Framework Law on the Environment (2008).

CITES compliance

At an international level, analysis of CITES trade records of ball pythons exported from range states reveals cases of missing data (e.g., missing export records for Benin, Fig. 2), potential mis-reporting (e.g., under-reporting of annual exports by Togo) and frequent exceeding of nationally established export quotas (Fig. 3, Suppl. material 1). In addition, there is evidence that snakes exported from a particular country were in fact sourced from neighbouring range states without adequare documentation (D'Cruze et al. 2020b) potentially negating conservation measures taken within other countries.

Discrepancies between export and import data in the CITES trade database are common (e.g., Phelps et al. 2010) and may arise for a number of legitimate reasons (e.g., specimens leaving a country at the end of one year, and arriving at their destination at the beginning of the following year, in which case the same shipment is recorded at export and import under different years, UNEP-WCMC 2013) – they may also reveal irregularities and deliberate under-reporting but these are not possible to distinguish from genuine reporting errors. Over-reporting by exporters can arise when the exporting country reports the number of specimens permitted for export rather than the actual number of specimens exported (UNEP-WCMC 2013).

All three countries exceeded quotas for both ranched and wild-sourced exports in at least one year, but vast differences in quotas mean that the implications of doing so differ. Exceeding a very low, conservatively established, quota, for example, may represent a lower risk in terms of potential over-exploitation than trading within the limits of a very high quota.

Trade links

Although some trade is formally documented between these three range states it is not clear to what extent CITES-recorded trade is representative of the actual inter-state trade that occurs in this region. For example, whilst Ghanaian exports include a proportion that originates from other range states there are discrepancies in the numbers traded between Benin and Ghana, and in source codes between Togo and Ghana, meaning that total regional exports (and their origins) are difficult to reliably quantify, and compliance with CITES trade quotas difficult to assess. For example, in 2012, Benin reports exporting 2,950 ball pythons to Ghana, whereas Ghana reports importing 10,500 Ball pythons from Benin–there are no transactions in either previous or later years that appear to account for the difference of almost 7,000 ball pythons.

Similarly, in 2014, Togo reported exporting 2,500 ranched ball pythons to Ghana but whilst Ghana reports importing 2,200 ranched ball pythons from Togo the following year (which may or may not be the same snakes) they also report importing 500 ball pythons born in captivity and 50 wild-sourced ball pythons in 2014 that do not appear in Togo's export records. The involvement of other range states, albeit at a relatively lesser level, and changes in the states involved over time, suggests that, as has been observed for other species in trade (e.g., pangolins, Heinrich et al. 2016), this regional network is dynamic and may be subject to change in response to relative abundance of snakes across their range, and economic interests of neighbouring states.

That ball python hunters also hunt in neighbouring countries, and sell pythons caught in one country to snake farms in another (D'Cruze et al. 2020b) introduces further complications. In reality CITES-reported exports from Benin, Ghana and Togo are composed to at least some degree of snakes sourced informally (or illegally) from neighbouring countries (see also Gorzula et al. 1997; Owusu-Nsiah 1999).

Sustainability

Sustainability is difficult to assess in the absence of wild population data. Although harvest size is often monitored in lieu of wild population size, harvest may be influenced by effort (hunting period, numbers of hunters, and area hunted) and the methods used, all of which may vary over time (Weinbaum et al. 2013 and references therein). Thus, whilst, for example, declining exports from Benin may indicate declining wild populations, it could also indicate shifting focus of local income opportunities, and it does not necessarily follow that relatively stable exports from Togo indicate stable wild populations. There are no accurate wild population data available (i.e. based on robust density estimates) for this species in any part of their range (Auliya and Schmitz 2010) but 75% of Togolese hunters surveyed by D'Cruze et al. (2020b) reported that there were fewer snakes than there were five years previously, and several commented that they had to travel further to find them.

Ball python exports from all three countries are dominated by a small number of export companies (although it is possible that there are more that export exclusively

to parts of the world other than the USA), and the number of companies operating in Benin and Ghana appears to have declined (although it is not possible to distinguish between a decline in the number of companies and a decline in the number of companies exporting to the USA). Further, shifting global trends (in market demand, Suppl. material 2) and increasing competition from captive-bred sources from the USA (e.g. Herrel and van der Meijden 2014) and some European countries, suggests that trade in individuals sourced directly from range states may itself not be sustainable in the long-term at present quantities.

The wider aspects of this trade: for example, risks of genetic pollution and/or disease introduction associated with improper re-release of snakes from ranches, and concerns regarding poor animal welfare at farms and in temporary holding facilities, together with documented additional uses in traditional medicine and bushmeat are discussed elsewhere (see Auliya et al. 2020, D'Cruze et al. 2020c, d, e). All such issues are potentially accentuated in a system whereby snakes are hunted and traded in convoluted trade chains throughout the region as described here (based on CITES trade patterns), and in D'Cruze et al. (2020b) (based on hunter questionnaires).

Recommendations

A multidisciplinary review in Togo (Auliya et al. 2020; D'Cruze et al. 2020b, c, d, e) has raised concerns as to whether ball python production methods are sustainable, humane and/or compliant with current legislation and other management protocols. To inform effective and evidence-based policy decision-making, D'Cruze et al. (2020e) recommended that the CITES scientific authorities in Togo should develop and initiate a scientific research programme to determine: (1) the distribution, population status, and population trends of ball pythons; and (2) demographic parameters of wild populations, including the reproductive output of wild and ranching-affected females, and (3) the morbidity and mortality rates of ball pythons during collection and transport from the point of harvest to the exporter's premises, prior to export. We suggest that the proposed research should be extended to Benin and Ghana.

Previous reviews of ball python production methods in West Africa have recommended a tripartite approach between the three main ball python exporters in West Africa (Benin, Ghana, and Togo) to ensure an effective regional-level conservation management plan for this species (e.g., de Buffrénil 1995). Key concerns highlighted here are: (1) improperly recorded cross-border ball python trade (together with unregulated cross-border hunting described in D'Cruze et al., 2020b); (2) inconsistent use of CITES codes; and (3) non-compliance with domestic legislation (see also D'Cruze et al. 2020e; Auliya et al. 2020). All of these potential issues could, arguably, be better addressed by CITES management authorities in Benin, Ghana, and Togo working together, coordinating efforts, and ensuring consistency in practices undertaken, regulation and legislation. To date, recommendations for this type of coordinated approach have not been officially acted upon.

At an international level, ball pythons have been included in a number of CITES driven processes in recent years but these have not taken the regional dynamics of py-

thon production into account. Specifically, at the CITES Conference of the Parties in 2016 (CoP17) Benin was encouraged to: (1) design and implement a management program for the species; (2) make non-detriment findings based on studies of the species, basic demographics, harvest and trade in the species; and (3) strengthen national regulations relating to trade control and monitoring, including stricter control policies for production systems (Dec. 17.276). However, at Animals Committee 30 the CITES Secretariat reported that Benin had not provided this information as requested. With regards to Togo, the ball python was not included in the Review of Significant Trade at Animals Committee 29 due to the incorrect assumption that it was already included in CITES Decisions (Dec. 17.276). To date, it appears that Ghana has not been requested to provide any similar information to CITES despite its prominent role in ball python production in West Africa. Instead of extending Decision 17.276 after the CoP18 in 2019, The United Nations Environment Programme – World Conservation Monitoring Centre was instead requested to "pay particular attention to *Python regius* from Benin, when performing its initial analysis of trade data" (CoP 18 Doc. 25). We recommend that this request be extended to Togo and Ghana. We also reiterate the recommendation that ball pythons in Benin, Togo, and Ghana should be considered for inclusion in future CITES procedures [e.g., Reviews of Significant Trade procedures (that would specifically delve into the sourcing of ball pythons from the wild), or Trade in Animal Specimens Reported as Produced in Captivity (that would focus on other issues related to those snakes reported as ranched)] at the next Animals Committee meeting.

Conclusions

This regional-level analysis reveals inconsistencies in management approaches among the three countries, and raises some concern regarding the sustainability of ball python trade in this region. It is clear that robust scientific information, that is currently lacking, is needed to determine the full current impact of the large scale international commercial trade on wild ball python populations and that this needs to be translated into policy in a cohesive way, particularly at a regional level in West Africa. Our findings, together with other recent studies in Benin and Togo (Toudonou, 2015; Auliya et al. 2020; D'Cruze et al. 2020b) suggest that export quotas and other management decisions are currently being made on an *ad hoc* commercial rather than scientific basis. The importance of this trade in terms of local livelihoods throughout the region (see e.g. D'Cruze et al. 2020b), particularly with respect to shifting global trade patterns and increasing competition for market supply from captive-bred sources in the USA and Europe (Suppl. material 1) (as well as the availability of, and adaptability to, alternative sustainable forms of income) also warrants further investigation. Ultimately, local livelihoods based on ball python exploitation are dependent on sustainability and continued market demand. The former depends on evidence-based and well-regulated wildlife management. The latter may (with increasing recognition of reptile sentience [Lambert et al. 2019], animal welfare [Baker et al. 2013], and public health risk [Moorhouse et al. 2017]) depend on evidence that the trade is sustainable, legal, safe (from a public health perspective), and humane.

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References

Affre A, Ineich I, Ringuet S (2005) West Africa, Madagascar, Central and South America: Main origins of the CITES-listed lizard pet market in France. Herpetological Review 36: 133–137.

Aubret F, Bonnet X, Shine R, Maumelat S (2003) Clutch Size manipulation, hatching success and offspring phenotype in the ball python (*Python regius*). Biological Journal of the Linnean Society. Linnean Society of London 78(2): 263–272. https://doi.org/10.1046/j.1095-8312.2003.00169.x

Auliya M, Schmitz A (2010) *Python regius*. The IUCN Red List of Threatened Species 2010: e.T177562A7457411. https://doi.org/10.2305/IUCN.UK.2010-4.RLTS.T177562A7457411.en [Downloaded on 22 February 2018]

Auliya M, Hofmann S, Segniagbeto GH, Assou D, Ronfot D, Astrin JJ, Forat S, Koffivi K, Ketoh G, D'Cruze N (2020) The first genetic assessment of wild and farmed ball pythons (Reptilia, Serpentes, Pythonidae) in southern Togo. Nature Conservation 38: 37–59. https://doi.org/10.3897/natureconservation.38.49478

Ayilu RK, Antwi-Asare TO, Anoh P, Tall A, Aboya N, Chimatiro S, Dedi S (2016) Informal artisanal fish trade in West Africa: Improving cross-border trade. Penang, Malaysia: WorldFish. Program Brief: 2016-37. https://www.worldfishcenter.org/content/informal-artisanal-fish-trade-west-africa-improving-cross-border-trade-0

Baker SE, Cain R, van Kesteren F, Zommers ZA, D'Cruze N, Macdonald DW (2013) Rough Trade: Animal Welfare in the Global Wildlife Trade. Bioscience 63(12): 928–938. https://doi.org/10.1525/bio.2013.63.12.6

Barker DG, Barker TM (2006) Pythons of the World. Volume II: Ball pythons. VPI Library, Boerne, Texas, USA, 320 pp.

Bassey E, Nkonyu L, Dunn A (2010) A reconnaissance survey of the bushmeat trade in eight border communities of South East Nigeria, September–October 2009. The Wildlife Conservation Society. https://pdfs.semanticscholar.org/f3d9/00d907f560f7c0fd7a3e2f0e9471fb4f42ed.pdf

Blundell AG, Mascia MB (2005) Discrepancies in Reported Levels of International Wildlife Trade. Conservation Biology 19(6): 2020–2025. https://doi.org/10.1111/j.1523-1739.2005.00253.x

Bräutigam A, Howes J, Humphreys T, Hutton J (1994) Recent information on the status and utilization of African pangolins. Traffic Bulletin 15: 15–22. https://www.traffic.org/bulletin/ [REMOVED HYPERLINK FIELD]

Carpenter AI, Rowcliffe JM, Watkinson AR (2004) The dynamics of the global trade in chameleons. Biological Conservation 120(2): 291–301.

D'Cruze N, Paterson S, Green J, Megson D, Warwick C, Coulthard E, Norrey J, Auliya M, Carder G (2020a) Dropping the Ball? The Welfare of Ball Pythons Traded in the EU and North America. Animals (Basel) 10(3): 413. https://doi.org/10.3390/ani10030413

D'Cruze N, Harrington LA, Assou D, Ronfot D, Macdonald DW, Segniagbeto GH, Auliya M (2020b) Searching for Snakes: Ball Python Hunting in Togo, West Africa. Nature Conservation 38: 13–36. https://doi.org/10.3897/natureconservation.38.47864

D'Cruze N, Assou D, Coulthard E, Norrey J, Megson D, Macdonald DW, Harrington LA, Ronfot D, Segniagbeto GH, Auliya M (2020c) Snake Oil and Pangolin Scales: Insights into Wild Animal Use at "Marché des Fétiches" Traditional Medicine Market, Togo. Nature Conservation 39: 45–71. https://doi.org/10.3897/natureconservation.39.47879

D'Cruze N, Bates J, Assou D, Ronfot D, Coulthard E, Segniagbeto GH, Auliya M, Megson D, Rowntree J (2020d) A Preliminary Assessment of Bacteria in "Ranched" Ball Pythons (*Python regius*), Togo, West Africa. Nature Conservation 39: 73–86. https://doi.org/10.3897/natureconservation.39.48599

D'Cruze N, Harrington LA, Assou D, Macdonald DW, Ronfot D, Segniagbeto G, Green J, Auliya M (2020e) (in press) Betting the Farm: A Review of Ball Python Trade from Togo, West Africa. Nature Conservation.

de Buffrénil V (1995) Les élevages de Reptiles du Bénin, du Togo et du Ghana. Rapport d'étude réalisée pour le Secrétariat de la CITES, Juin 1995: 1–23. https://www.cites.org/sites/default/files/common/com/ac/25/F25i-03.pdf

Eniang EA, Akpan CE, Enian ME (2008) A survey of African grey parrots (*Psittacus erithacus*) trade and trafficking in Ekonganaku Area of Ikpan Forest Block, Nigeria. Ethiopian Journal of Environmental Studies and Management 1(2): 68–73. https://doi.org/10.4314/ejesm.v1i2.41583

Gorzula S, Nsiah WO, Oduro W (1997) Survey of the Status and Management of the Royal Python (Python regius) in Ghana. Part 1. Report to the Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Geneva, Switzerland, 1–38. http://ec.europa.eu/environment/cites/pdf/studies/royal_python_ghana.pdf

Harris M (2002) Assessment of the status of seven Reptile species in Togo. Report to the Commission of the European Union, réf. EC 9810072: 1–58. http://jncc.defra.gov.uk/pdf/togo_sevenreptilespeciesvpt1.pdf

Heinrich S, Wittmann TA, Prowse TAA, Ross JV, Delean S, Shepherd CR, Cassey P (2016) Where did all the pangolins go? International CITES trade in pangolin species. Global Ecology and Conservation 8: 241–253. https://doi.org/10.1016/j.gecco.2016.09.007

Herrel A, van der Meijden A (2014) An analysis of the live reptile and amphibian trade in the USA compared to the global trade in endangered species. The Herpetological Journal 24: 103–110. https://pdfs.semanticscholar.org/f6de/4cb2d4834b56dfde6bd577de907e7fa1f65e.pdf

Hyndman RJ (2017) forecast: Forecasting functions for time series and linear models. R package version 8.2. https://pkg.robjhyndman.com/forecast/

Ineich I (2006) Les élevages de reptiles et de scorpions au Bénin, Togo et Ghana, plus particulièrement la gestion des quotas d'exportation et la définition des codes "source" des spécimens exportés. Rapport d'étude réalisée pour le Secrétariat de la CITES. Projet CITES A-251: 1–113.

Jensen TJ, Auliya M, Burgess ND, Aust PW, Pertoldi C, Strand J (2019) Exploring the international trade in African snakes not listed on CITES: Highlighting the role of the internet

and social media. Biodiversity and Conservation 28(1): 1–19. https://doi.org/10.1007/s10531-018-1632-9

Krishnasamy K, Shepherd CR, Or OC (2018) Observations of illegal wildlife trade in Boten, a Chinese border town within a Specific Economic Zone in northern Lao PDR. Global Ecology and Conservation 14: e00390. https://doi.org/10.1016/j.gecco.2018.e00390

Lambert H, Carder G, D'Cruze N (2019) Given the Cold Shoulder: A review of the scientific literature for evidence of reptile sentience and cognition. Animals (Basel) 9(10): 1–22. https://doi.org/10.3390/ani9100821

Leader-Williams N (2002) When is international trade in wild animals detrimental to survival: principles, avoidance and monitoring? In: Rosser A, Haywood M (Eds) Guidance for CITES scientific authorities: checklist to assist in making non-detriment findings for Appendix II exports. World Conservation Union: 7–16.

Luiselli L, Angelici FM (1998) Sexual size dimorphism and natural history traits are correlated with intersexual dietary divergence in royal pythons (*Python regius*) from the rainforests of southeastern Nigeria. The Italian Journal of Zoology 65(2): 183–185. https://doi.org/10.1080/11250009809386744

Lyons JA, Natusch DJD, Jenkins RWG (2017) A Guide to the application of CITES source codes. International Union for Conservation of Nature (IUCN). Rue Mauverney 28: 1196. [Gland, Switzerland]

Mangiafico S (2019) rcompanion: Functions to Support Extension Education Program Evaluation. R package version 2.0.10. https://CRAN.R-project.org/package=rcompanion

McCurley K (2005) Ball pythons in captivity. Livingart Publishing, Lansing, Missouri.

Moorhouse TP, Balaskas M, D'Cruze NC, Macdonald DW (2017) Information Could Reduce Consumer Demand for Exotic Pets. Conservation Letters 10(3): 337–345. https://doi.org/10.1111/conl.12270

Nowak K (2019) In the Alaska-Yukon wilderness, wildlife crime fighters face a daunting task. National Geographic 25(June): •••. https://www.nationalgeographic.com/animals/2019/06/yukon-alaska-wildlife-crime/

Outhwaite W, Brown L (2018) Eastward Bound: Analysis of CITES listed flora and fauna exports from Africa to East and Southeast Asia 2006 to 2015. TRAFFIC International, Cambridge, United Kingdom. www.traffic.org/publications/reports/eastward-bound/

Owusu-Nsiah W (1999) Exploitation, husbandry and trade in royal python (*Python regius*) in Ghana - Exploitation, elevage et commerce du python royal (*Python regius*) au Ghana. Nature et Faune - Wildlife and Nature 15: 13–27.

Pernetta AP (2009) Monitoring the Trade: Using the CITES Database to Examine the Global Trade in Live Monitor Lizards (*Varanus* spp.). Biawak 3: 37–45.

Phelps J, Carrasco LR, Webb E, Koh L, Pascual U (2010) Boosting CITES. Science 330(6012): 1752–1753. https://doi.org/10.1126/science.1195558

Prestridge HL, Fitzgerald LA, Hibbitts TJ (2011) Trade in non-native amphibians and reptiles in Texas: Lessons for better monitoring and implications for species introduction. Herpetological Conservation and Biology 6: 324–339. http://www.sierraherps.com/files/3513/2607/5853/Prestridge_etal_2011_TX_herp_trade.pdf

R Core Team (2018) R: A language and environment for statistical computing. R Foundation for Statistical Computing (Vienna). https://www.r-project.org/

Robinson JE, Griffiths RA, St. John FAV, Roberts DL (2015) Dynamics of the global trade in live reptiles: Shifting trends in production and consequences for sustainability. Biological Conservation 184: 42–50. https://doi.org/10.1016/j.biocon.2014.12.019

Secretariat CITES (2012) CITES Trade: recent trends in international trade in Appendix II-listed species (1996-2010). Prepared by UNEP-WCMC, Cambridge. https://cites.unia.es/cites/file.php/1/files/CITES-trade-recent-trends.pdf

Segniagbeto GH, Petrozzi F, Aïdam A, Luiselli L (2013) Reptiles Traded in the Fetish Market of Lomé, Togo (West Africa). Herpetological Conservation and Biology 8: 400–408. http://www.herpconbio.org/Volume_8/Issue_2/Segniagbeto_etal_2013.pdf

Selier SAJ, Page BR, Vanak AT, Slotow R (2014) Sustainability of elephant hunting across international borders in southern Africa: A case study of the greater Mapungubwe Transfrontier Conservation Area. The Journal of Wildlife Management 78(1): 122–132. https://doi.org/10.1002/jwmg.641

Shepherd CR, Nijman V (2007) An assessment of wildlife trade at Mong La market on the Myanmar-China border. Traffic Bulletin 21: 85–88. https://www.traffic.org/bulletin/

Toudonou CAS (2015) Ball python *Python regius*. https://cites.unia.es/cites/file.php/1/files/id_material/assessment_impact_pet_trade_case_study_Python_regius.pdf

UNEP (2019) The Species+ Website. Nairobi, Kenya. Compiled by United Nations Environment Program, World Conservation Monitoring Centre, Cambridge, UK., Cambridge, UK. www.speciesplus.net [Accessed August 2019]

UNEP-WCMC (2013) A guide to using the CITES Trade Database. Version 8, October 2013. United Nations Environment Program, World Conservation Monitoring Centre, Cambridge, UK. https://trade.cites.org/cites_trade_guidelines/enCITES_Trade_Database_Guide.pdf

Weinbaum KZ, Brashares JS, Golden CD, Getz WM (2013) Searching for sustainability: Are assessments of wildlife harvests behind the times? Ecology Letters 16(1): 99–111. https://doi.org/10.1111/ele.12008

Supplementary material 1

Figure S1

Authors: Lauren A. Harrington, Jennah Green, Patrick Muinde, David W. Macdonald, Mark Auliya, Neil D'Cruze

Data type: CITES trade data

Explanation note: Annual ball python exports from range states shown against quotas.

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Supplementary material 2

Figure S2

Authors: Lauren A. Harrington, Jennah Green, Patrick Muinde, David W. Macdonald, Mark Auliya, Neil D'Cruze

Data type: CITES trade data

Explanation note: Global maps showing destination countries for ball pythons exported from Benin, Ghana and Togo.

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Link: https://doi.org/10.3897/natureconservation.41.51270.suppl2

Supplementary material 3

Main importing countries: additional data

Authors: Lauren A. Harrington, Jennah Green, Patrick Muinde, David W. Macdonald, Mark Auliya, Neil D'Cruze

Data type: Additonal data for main importing countries and regions

Explanation note: Annual import volume and supply countries for ball python imports to the USA, the EU and Hong Kong, and annual export volume, countries supplied and source for ball pythons exported from the USA.

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